Rebuilding the NAVSEA Early Stage Ship Design Environment

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ABSTRACT

It has been well over a decade since the last time the Naval Sea Systems Command (NAVSEA) performed a full blown preliminary and contract ship design. During that time period there have been many advances in the underlying technology used by design tools, and there have also been changes to the design process as well. As a result, NAVSEA has the responsibility to evaluate tools and processes in order to develop the next generation early stage ship design environment so that we do not continue to design tomorrow's ships with yesterday's tools. This paper discusses the role product model technology, high performance computing, and early stage design tools can play in the development of future naval vessels. The subject of design tools will be explored from the perspective of how they improve the early stage ship design process as well as their role in gaining insights and supporting oversight during the detailed design and construction phases of a ship's lifecycle.

NOMENCLATURE

CAD - Computer-Aided Design
CREATE – Computational Research and Engineering Acquisition Tools and Environments
HPC – High Performance Computers
ONR – Office of Naval Research
FEM – Finite Element Model
FEA – Finite Element Analysis
IGES – Initial Graphics Exchange Specification
NPDI – Navy Product Data Initiative
STEP – Standard for the Exchange of Product data (ISO 10303)
LEAPS – Leading Edge Architecture for Prototyping Systems
ASSET – Advanced Ship and Submarine Evaluation Tool
COTS – Commercial Off-the-Shelf Software

INTRODUCTION

Change is a permanent fixture within the US Naval Shipbuilding industry, to the acquisition process, and within the NAVSEA enterprise. It has been several years since an early stage design has been led and completed by the government (Keane et al. 2009). Major changes have occurred in both the sophistication of software products available to the marine industry as well as the available computing power. Open architectures and the availability of standards for the definition of product model data has the potential to improve the early stage design process. Of course, many issues arise when establishing a design site, but this paper only examines issues of product model technology, software, and early stage design tools. But one thing is for sure, the early stage knowledge embedded within the NAVSEA enterprise is retiring. The humans that managed, performed, and supported early stage ship design are all but gone. If the next generation of early stage ship designers are not deliberately trained, mentored, and given the tools they need to design 21st century ships within the next few years, there is a distinct possibility there will be none of the current generation left to pass on the trade.

A BRIEF HISTORY

Up through the 1990's design sites supporting the early stage design of surface ships and submarines were commonplace within NAVSEA (Ayers et al. 1998). These design sites could be found within NAVSEA office spaces, contractors' facilities, and at the Naval Ship R&D Center in Carderock, MD. They were staffed by a mixture of NAVSEA and Warfare Center employees and resources obtained from local Naval Architecture firms. Depending on the acquisition strategy, some of the design teams would include the shipyards that may be bidding on the detailed design and construction. During these bygone days, NAVSEA was deeply involved in the use and customization of commercial CAD systems, the continuous evaluation of commercial Naval Architecture tools, and where necessary, the development of specific design tools. NAVSEA, as

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well as any major enterprise involved in the design of their products struggled with the balance between the use of commercially available software and the in-house development of software. This problem was compounded by the relatively small size of the marine sector coupled with trying to define the Navy's core competencies in software development. During the acquisition reform of the mid-nineties, many of the responsibilities traditionally assigned to the NAVSEA engineering directorate were transferred to the industrial sector. One critical result was less Navy engineering and more Navy engineering oversight. The old adage goes "you forget what you hear, you remember what you see, and you know what you do." Because NAVSEA is not doing ship design, it is missing an opportunity to pass on corporate engineering knowledge to the next generation of ship designers, ship design managers, and design integration managers. The time is ripe for NAVSEA to rebuild its early stage design competency. With improvements in information technology, we are afforded an opportunity to integrate cutting edge information technologies with established analysis tools and the knowledge of an aging workforce.

THE CASE FOR TOOL DEVELOPMENT

Ships are large and complex products and have a long development cycle. It is widely recognized throughout the engineering world that decisions made during the conceptual design phase have the largest impacts on cost, performance, and schedule. Many of the critical requirements levied on a warship require complex analysis to verify that they are met (such as hull fatigue life, vulnerability/shock performance, signatures, and topside sensing/communication performance). These complex analyses require a high level of design definition, which is typically not available until the detailed design and construction phase. In the current design paradigm, analysis results that verify if a ship design meets its requirements come after their opportunity to influence the design. Because of the limited amount of tool integration, and a manual ship design definition process, the Navy enterprise usually driven to select one design alternative early in the design process. Much of the rest of the design effort is spent detailing and reworking this single alternative to meet the requirements and cost goals.

The vision for Navy design tools is to move to a automated high-end toolset that integrates many information dense design definition tools with high fidelity physics-based analysis tools. This toolset will be able explore many ship design alternatives to populate a feasible design space. This design space will be used to perform real time cost-benefit trades on ship requirements during the requirements definition process. A system such as this could be used to explore the design space to ensure that the correct design is selected before signing a contract to build a ship.

Direction on this was given to NAVSEA in February of 2008 in a memo from Admiral Sullivan, who was then COMNAVSEA, which outlines types of tools and tool developments needed. The memo sates that,

> Accomplishing these ambitious goals will be a challenge, but is essential for crafting affordable, executable ship programs in an increasingly complex national security environment. Previous Navy design tool investment has resulted in the Advanced Ship and Submarine Evaluation Tool (ASSET) for total ship synthesis, and the Leading Edge Architecture for Prototyping Systems (LEAPS) for integrating a wide range of analysis tools in a common data environment. Future tool development should build upon these foundations, adding capability to meet the goals outlined in this memorandum. [Ser 05D/047, 4 Feb 2008]

ASSET is software that has been built and maintained by the Navy at NSWC Carderock for over 25 years, and it is currently the principal tool used in earliest stages of ship design. ASSET is unique in that it combines ship design disciplines into one synthesized whole-ship model that represents a balanced design. A major issue is that ASSET does not produce the level of design definition required for many of the higher-level analyses required in the later stages of ship design. When a design progresses beyond concept design, where a more detailed analysis is needed, the design integration provided between disciplines by ASSET is lost. Existing analysis tools typically require their own custom format of input data. Up to 90% of the time spent on these analyses is spent preparing the input, which often means manually recreating design data that was already created in another tool. This data recreation accounts for most of the time, cost, and error associated with analysis.

The effort to solve this time-delay and configuration control issue between high-end tools is LEAPS. LEAPS is also developed and maintained by the Navy at NSWC Carderock, and has been a 15-year effort. At its base LEAPS is a digital representation of the ship designed to be expansible to include all information necessary to perform any relevant analysis and store the results of those analyses for use by other analyses. It is the hub, while detailed discipline-specific tools represent the spokes in a ship design cycle. Careful though and planning is required to bring a LEAPS based design and analysis for a new ship to fruition. What design and analysis activities are performed at each phase of the design should be planned carefully to ensure that the information is created before it is required. The way that design tools interact is directly related to the way we design ships, and the way people think about design. The process that forms the foundation of ASSET reflects the roles and responsibilities of NAVSEA at the time ASSET was created. Efforts are currently underway to map the entire ship design process so that gaps in the ship design toolset can be identified. This map will also allow NAVSEA to engineer and streamline the ship design process. This effort is tied to the NAVSEA Tools Roadmap development and semi-annual workshops sponsored by NAVSEA, ONR, and the CREATE program, but this is a subject for another paper.

CREATE (Computational Research and Engineering Acquisition Tools and Environments) is a DoD program that is focused on tackling many of these challenges. The program is run out of the DoD High Performance Computers Modernization Office (HPCMO). CREATE-SHIPS (a portion of the overall CREATE program) is budgeted to spend several million dollars from HPCMO over the next few years, and focuses on leveraging the modern increases in computational power to develop the high-end toolset and enable this process of rapidly designing and analyzing large number if ship designs. CREATE-SHIPS is a partnership between NAVSEA, ONR, HPCMO, and PEO SHIPS. Another positive step at NAVSEA was the establishment of the Technical Warrant Holder position for Ship Design Tools in October of 2008 as a step towards raising the importance of ship design tools in the overall design and certification process. In December 2009, this position was moved to the NAVSEA 05 Chief Technology Office as the Tools Program Manager, further elevating the importance of tool development to the NAVEA enterprise.

In addition to the issue of configuration between disciplines, many aspects of ship design do not have sufficient tools and models in existence, and increasingly rely on engineering judgment and large factors of safety. For instance, we are often looking at new and innovative ways to estimate a ship's manning requirements or costs at an early stage. But developing and improving the individual high-end tools themselves is not as simple as implementing a theory into a computer algorithm. Tools need to be verified and validated; problems must be easy to set up and run; geometry and mesh generation must be easy and quick; tools must be built to run effectively and efficiently on highly complex massively parallel computers; and, results must be timely. Many of the tools we use are highly specialized, and not used beyond the narrow realm of Naval ship design. The results of these complex analyses must be visualized and packaged in a way that they are easy to understand by both the design engineers and program managers such that they can be the basis of a smart, timely decision making process.

A CREATE effort of note is the development of the Integrated Hydrodynamics Design Environment (IHDE). For ship hydrodynamics a large set of specialized commercial, government, and even university built research tools and models is used for all aspects of ship hydrodynamics such as resistance, seakeeping, stability, and fluid-structure interactions. Most of these tools are highly specialized and only experts can run them. The IHDE, now in its second year of development, seeks to provide a unified easy-to-use system that gives a ship designer the ability to interface more directly with these tools. It also has the ability to create input files from ship design data available in the LEAPS representation of the ship automatically, and to store the results of the analysis back into LEAPS.

Figure 1 The Integrated Hullform Design Environment ties together several hydrodynamics tools

Another software development worthy of discussion here is Intelligent Ship Arrangements (ISA), which is a tool in its infant stages developed as

a research project at the University of Michigan and not yet transitioned to Navy use. As mentioned earlier, many cases an analysis cannot be performed due to a lack of the design definition needed. A major hurdle is that ship arrangements—the way that compartments and machinery are laid out relative to one another—is an intensive manual process and often considered more art than science because of the unlimited number of viable solutions. This tool looks at the arrangements within a ship's hull as an industrial engineering problem, a hybrid of efficiently packing a box and laying out circuitry on a microchip, and arranges the ship according to constraints and rules set by the users ahead of time. When used in a systematic and stochastic way, and when integrated using LEAPS, having this type of design information early in the design process can feed into analyses such as manning, vulnerability, producibility, and a number of other "ilities" in time to influence major ship design decisions.

Ultimately, our goal is to shrink the time required to generate a sufficient amount of information to make informed design decisions early in the ship design process before the requirements are set and cost of the ship is locked in. By considering an integrated computational ship model as a "virtual prototype," several design iterations are possible in a far shorter amount of time than a single design-build-test cycle of a traditional prototype.

One commercial example illustrates what we can now achieve with this paradigm. In the early 1990s, Goodyear Tire faced intense international competition. Its rivals had more engineering design resources, testing capacity, and lower production costs—Goodyear was rapidly falling behind. To respond and develop a competitive advantage, it replaced the traditional engineering process (design, build, test, and repeat) that had served it well for more than 100 years with physics-based computational engineering tools to design, mesh, and analyze new products. Engineers built and tested just the final, optimized designs, thereby reducing Goodyear's time to market from three years to less than a year. The company started producing several new designs a year instead of one or two every few years. Goodyear is now the largest US tire manufacturer and is competitive in the world market. Whirlpool, Proctor and Gamble, Boeing, Ping Golf, and Pratt and Whitney, to name a few, have also adopted this new paradigm with similar success.

In addition, Systems Engineering tools and methodologies such as Set-Based Design along with techniques for Design of Experiments and Multi-Disciplinary Optimization can help integrate seemingly disparate types of analysis. Stochastic analysis, now available to us through automation and high-speed computing, will not only allow us to better capture uncertainty into the design process, but it allows several single aspects of a ship design to be explored comprehensively on their own before comparing them to ensure convergence and feasibility of the ship design as a whole. In addition to linking ship structures, hydrodynamics, and susceptibility models for instance, the front end can link to force models and the back end can link with cost and affordability models to provide a full picture to decision makers so that timely decisions can be made with confidence.

AN INTRODUCTION TO EARLY STAGE SHIP DESIGN

Decisions made early on in the ship design process have large impacts on ship functionality that isn't quantified until the design is mature. Often these impacts are only vaguely understood at the outset of the design cycle, and by the time that the impacts are fully understood it is too late to make significant changes. An example of this could be the vulnerability of the ship: in order to asses a ship's vulnerability, a detailed layout of compartments and distributed systems is needed, but early on in the ship design, when sizing decisions are made, detailed layouts are not available and a ship designer has little more than rules-of-thumb to base these crucial decisions upon. With High Performance Computing (HPC) as an enabler, the vision is to explore all downstream implications of decisions made during the initial concept development and apply that knowledge as early on in the design process as possible. In the vulnerability example used above, for instance, an automated tool (such as ISA mentioned earlier) could rapidly produce a full range of feasible ship arrangements from a basic shell of a ship, and then a vulnerability assessment could be performed on each of these many design variations and the resultant range of achievable levels of vulnerability

can be fed back to the designer—with all of the high-speed computation happening behind the scenes. Thus, the designer is instantly aware of the vulnerability implications of the sizing and arrangement of the ship.

Design Spiral versus Set-Based Design

Naval Ship Design involves complex interactions between many disciplines, and reconciling the needs of one system against others becomes a delicate balancing act. The convergence of various discipline-specific ship models into a single coherent design is a process that NAVSEA has termed "Ship Synthesis," and is currently chiefly performed using the Navy's in-house tool ASSET. ASSET is made up of discipline specific modules (i.e. hull geometry, gross arrangement, hull structural design, resistance and propulsion, power plant sizing, weight estimation, and area/volume sufficiency analysis). ASSET performs synthesis between these modules using a design spiral approach. This means that disciplines are analyzed one at a time before moving to the next one, and multiple iterations are performed through the spiral process in order to converge into a single solution. Each loop is a serial process that must be done in order, and control of each design variable must be carefully managed. The modules in ASSET are highly coupled so that the dynamic process of synthesis is stable and converges on a solution.

In a Set-Based Design approach, which has been identified as a preferred approach for the development of future U.S. Naval design efforts, discipline-specific designs are done in parallel across a broad design space. This process is designed to improve the flexibility of the design by delaying key decisions until the design space is fully understood, but the parallel nature of the approach also makes it an ideal fit for HPC application. Currently, set-based design, as practiced in the Navy's Ship-to-Shore Connector program, relies on engineering interaction and judgment for creating the set information from each discipline and integrating the results from multiple disciplines in order to find a set of possible solutions. But techniques known as Multi-Disciplinary Optimization (MDO) offer the infrastructure for integrating the set based design theory into Navy ship design tools in a mathematically rigorous and automated manner. Applications of MDO techniques to ship synthesis are ready to be tested and implemented and are moving forward. Due to the highly coupled, multivariate nature of the ship design problem, MDO will be challenging, but holds great promise as an integrating agent.

The Navy Business Model

It is important at this point in the discussion to recognize the business environment in which the Navy designs ships. Although the details of ship procurement seem to change weekly, the basic initial design process remains generally the same. In the initial phase a large design space of many options is explored to a low level of fidelity, and with each successive phase of the design, guidance is given to the designer by a decision maker and the fidelity of the design is increased along with a decrease in the range of options available. This process is depicted graphically in Figure 2. As the design space starts to become defined, higher order models can be substituted into the Ship Synthesis process. HPC tools, such as the ones being developed under the CREATE Hydro and Shock projects, can become appropriate higher order models when the design space becomes sufficiently defined, and as these tools become faster and more accessible, they can be used in earlier phases of the design.

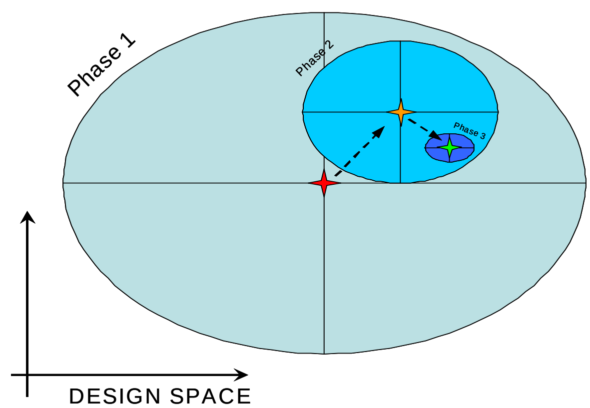

Figure 2 As the fidelity of the design increases, the design space under consideration gets smaller.

HPC tools for other disciplines, beyond just hydrodynamics and shock, need development as well, and an analysis of which disciplines hold promising theories that are applicable to solution by HPC (i.e.

large amounts of numerical calculations) should be done, and investments should be made in those areas. An example of this is the Intelligent Ship Arrangement technique under development at the University of Michigan, which was mentioned earlier in the paper.

ASSET Evolution

The vision for future ASSET is to expand its ship definition and analysis capability. Ship definition capability will be greatly enhanced through the use of a 3D NURBS based geometry definition/manipulation, arrangements, and component placement capability. This capabiltiy will come through the conversion of the ASSET data model into a LEAPS data model. This will allow the rapid turnaround between this design tool and higher fidelity physics models that require complicated mesh-able geometry and detailed ship design information. Arrangement details such as topside design and distributed system routing/architecture will make it possible to assess topside effectiveness and vulnerability during concept design. Pre-defined components will be stored in a LEAPS database and used in the ASSET model. ASSET will be run in a batch mode to create hundreds or thousands of feasible design variants that will be analyzed to determine their effectiveness.

Using Behavior Models

In order to use higher order models within a Ship Synthesis process and get results in a timely manner, the results of many runs of the higher order models must be abstracted into a "Behavior Model." These are sometimes also referred to as "Surrogate Models," or "Response Surfaces." The idea behind a Behavior Model is that from many discrete points in a design space, a continuous function can be closely fit, and that function can be queried instantaneously rather than re-running the computationally intensive higher order model. In this way, the Ship Synthesis process using full physics models can be done in real time. The design space can be explored or an optimization performed in a reasonable timeframe by a single user. Done in this manner, several higher order models in several disciplines can be run in a highly parallel way over a broad range of design space prior to the Ship Synthesis process. Figure 2 illustrates the process of defining a feasible design space in an initial phase of the design. Later an aspect of the design is explored in more detail using HPC tools, and a Behavior Model is developed from the results. This Behavior model can then be incorporated back into a Ship Synthesis in the next design phase. A similar approach to this was taken during the ONR HSSL effort, where seakeeping and resistance Behavior Models were developed based on parametric hullform changes, and these Behavior Models were used as part of Ship Synthesis. Using HPC, this effort was able to build these Behavior Models in two to three days rather than the 5,000 plus hours of computing time that it would have taken otherwise.

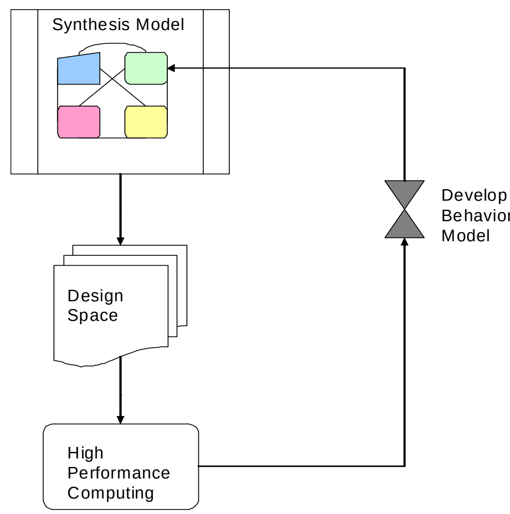

Figure 3. Higher order models used in successive design phases in the Ship Synthesis process can be Behavior Models created from HPC results.

Several mathematical models exist for developing Behavior Models, including polynomial splines, neural networks, and Kriging, and some are more appropriate than others for certain applications. These methods need to be characterized and developed into software that works within the Navy's ship design infrastructure and can be used in a parallel computing environment.

Leading Edge Architecture for Prototyping for Systems

LEAPS is a Navy developed environment for storing information about ship designs. It functions as a database that is capable of storing multiple ship

concepts, including detailed geometry information, numerical design information, system attribution, and behavior objects. A further discussion of LEAPS as a product model is discussed later in this paper.

Currently, CREATE Ships has funded the University of Michigan to update the database structure of LEAPS to enable queries to be made in parallel, enabling the use of LEAPS in a highly parallel computing job such as running many designs through multiple scenarios in a seakeeping analysis.

The DOD CREATE program, along with NAVSEA, is also currently developing the capability within LEAPS to parametrically distort a parent hullform so that a large design space can be created and run through HPC analysis tools such as those accessible from the Integrated Hydrodynamics Design Environment. This hullform manipulation toolkit is also an enabler for doing set-based design of the hullform in parallel with other aspects of the ship.

Planned Tool Improvements for the Concept Design Phase

In the concept design phase, the ship design organization should explore large sets of potential design alternatives using design space exploration and visualization methods. To use this method, an automated toolset is needed that can rapidly populate a design space with performance, cost, and risk data. There are several areas of improvement that have been identified to fill in a complete toolset for concept design. As we continue to identify and prioritize these, actions should be taken to improve those areas.

During this phase the level of detail may be relatively low, but the design is extremely dynamic. The process is dominated by synthesis tools and low level analysis. The emphasis during this phase is to identify solutions that are feasible. The majority of the design effort is performed using ASSET and a host of analysis tools that will quickly at a low level of detail identify windows of feasibility considering many variables including; cost, weight, arrangeable space, powering, and many others (Doerry 2009). The plan is to improve ASSET, build/integrate additional design and analysis tools, and provide a tighter integration with LEAPS (NAVSEA 05D 2008).

There are several products that are planned. These include Force Architecture Assessment and Operational Effectiveness Analysis. Plans are to integrate all of the design information into the LEAPS schema.

Preliminary/Contract Design

In the preliminary design phase, ship designers will continue to explore sets of potential design alternatives, but now to a higher level of fidelity and a less broad range. Design integration of a set based preliminary design will be challenging. Design space visualization is required to understand the whole ship impact of design decisions. As mentioned above, ASSET will be further integrated with LEAPS, so that higher fidelity preliminary design information can be replace the lower fidelity concept design information initially generated by the program. The program will also allow multiple users to work in parallel on different parts of the ship to speed the design definition process. In this phase of the design, the synthesis process will be much more focused on individual aspects of the design, which will be worked in great detail, whereas larger scale changes will be less common.

The Graphical User Interface (GUI) for ASSET will need to be much improved. ASSET of the future will feature a GUI that guides the user through the design process. The new GUI will allow the user to have point-and-click subdivision definition and interactive arrangement capability that will allow the user to see and manipulate the design in three dimensions. This GUI will allow the user to place machinery components, place topside equipment, and define distributed system runs using a three dimensional representation of the ship. The ability to place topside equipment on the three dimensional product model of the ship will allow ASSET to perform topside design. ASSET will also be able to interface with physics based topside analysis tools using a LEAPS interface. A topside design utility will feature a complete library of existing topside sensors, where pertinent design information has been pre-populated. The user will be able to define the necessary distributed system runs that will allow the ASSET model to be used to populate the data

necessary for vulnerability analysis. This will enable vulnerability analysis earlier in the design process. The ASSET GUI will allow the user to do general arrangements of the ship design, enabling the functional allocation of space to be made in the ship design process. This capability will allow the user to consider modularity during the design, and quantify how the placement of modules affects the general arrangement. Automated internal and topside arrangement capability is currently under development in the Intelligent Ship Arrangement tool.

A mission system component catalog will be developed. This data will be captured in a LEAPS database of group 400 (sensors and communications equipment) and 700 (weapons) systems that are found in existing ships, or being considered for future ships. The pedigree of the information will be stored in the LEAPS database along with each component to indicate if the system attributes are “as built” or were captured at some “non-final” stage. This database will be accessible and used as a primary payload database for ASSET. The component catalog will contain the component attributes necessary to determine the ship impact and perform the necessary analysis. The information will contain weight, area/volume, power, cooling, component specific location restrictions, and the specifics required for analysis (such as electromagnetic emissions). This data will be mined from certified data sources, and will therefore become the authoritative data set that can be referenced and used for future design studies. A process will be put into place to guide a user through the proper population of a mission system into ASSET. A mission system configuration utility will be added to ASSET to guide the user through a selection and placement process.

Functional Arrangement

During the preliminary design a greater emphasis is placed on optimizing the general arrangement by considering the location of equipment, outfitting, and routing lanes. The first iteration of the preliminary design LEAPS model is a product of the ASSET synthesis developed during the concept phase. The current process is heavily dependant upon commercial CAD tools where the geometry manipulation capabilities of the CAD system can be used to detail the arrangement. This process is heavily dependent on the existence of a reliable and efficient data exchange capability. It is envisioned that a limited portion of the arrangement function will be performed in an automated manner using the Intelligent Ship Arrangements (ISA) tool.

This evolving functional arrangement continues to be closely coupled to the hullform, many times requiring analyses typically associated with the concept phase. During this phase the level of detail is increasing, and more importantly the ship design is maturing. This enables more types of analysis to be performed in order to validate that the design meets the requirements. These types of analysis include; stability, vulnerability, survivability, shock, and a more in-depth evaluation of structural strength and fatigue performance, and hydrodynamic performance.

COTS VS. ORGANIC

This question has been haunting NAVSEA forever. During the mid 1980’s it became especially contentious in an era nostalgically referred to as “the CAD wars.” One faction was adamant that the only way NAVSEA could obtain design tools, including drafting tools was to have them developed in-house. The other faction was equally as adamant that the CAD industry could provide all tools necessary to support early stage ship design. We have since learned that a combination of COTS and organic design tools are necessary; although, we are not always properly performing this trade-off. We have also learned that most of the time COTS tools require some amount of customization to be useful for Navy design applications. The reality is that even the organic tools require a formal set of processes to ensure that they are used correctly. If a COTS package has the capability required, can reasonably be integrated into the design process, and proves to be the most cost effective solution, it should be used. NAVSEA has limited resources to develop and maintain in-house software, and it should be used to develop core Navy capabilities that commercial industry has no incentive to develop on it's own.

Integrating Design Tools

The Navy's plan is to implement LEAPS as the method for integrating the design information, and in

many cases, interacting design tools.. There are two options to using LEAPS as the design tools integrator. Option one is to modify design tools to directly use the LEAPS repository as their native database format. Option two is to create a translator that will extract that information required for performing the analysis and upon completion of the analysis will write the results back to the LEAPS repository. The first option is best for new tool development, while the second option may be more palatable for existing tools.

LEAPS AS A SOFTWARE ENVIRONMENT

LEAPS is a very powerful software environment that includes a CAD and math engine, and several useful toolkits. Both the LEAPS software and all of the supporting documentation is now approved for unlimited distribution, and is available to software developers for free if they want to use and even distribute it with their software. In return, the Navy hopes to have available many more software tools with the innate ability to extract and save ship data to LEAPS files. This year, we will be making LEAPS even more accessible by creating a web-based community of developers, where questions and examples can be exchanged, and LEAPS software and documentation downloaded. In addition, we continue to expand the user community of LEAPS through navy sponsored software development, where use of LEAPS is made contractual.

PROVIDING INFORMATION TO "THE OUTSIDE"

Digital product models have the ability to provide much more information about a ship than paper drawings. Information on design intent, engineering analyses, and inter-relation of systems can all be presented together, but as a technology the Navy is still learning to use it effectively. The issue, as we have learned, is that digital data formats come and go, and the lifetime of a CAD system is often shorter than the lifetime of a class of ship. Whereas, storing paper drawings amounts to a fairly trivial task, storing digital data has issues with computer systems, operating systems, and software systems that are all constantly changing and evolving. LEAPS provides the opportunity for the Navy to be stewards of their own digital data. Rather than relying on the constantly changing tide of the commercial sector, by defining and maintaining the LEAPS standard, the Navy can ensure that its own digital data stands the test of time. The optimal solution is a neutral file format that is not only product model agnostic, but transcends all phases of the ships lifecycle. The reality is that a compelling case can be made for archiving the native data along with one or more neutral representations. The key lies in having a thorough understanding of the context in which each format has the advantage and the pedigree of the information while maintaining strict configuration control. (Rakow, et. al. 2009) Surely maintaining LEAPS as a standard for ship design data must be recognized as a Navy core capability.

One of the major technical hurdles will be the method for providing this information to prospective bidders. From the perspective of the Navy, the easiest path would be to provide access to the LEAPS repository on a Navy controlled Integrated Product Data Environment. Another option worthy of exploration is to provide that information in a standards based neutral format. At this time the leading candidate for a neutral approach makes use of the Standard for the Exchange of Product Model Data (STEP). Although this may be the major milestone that would require digital data to be provided by the Navy, it is not the only time. The exchange of digital data is something that will be performed in a near continuous fashion to support collaboration during a lifecycle phase.

OBTAINING INFORMATION FROM "THE OUTSIDE"

Data exchange is required in both directions: especially to support a collaborative effort. During the Preliminary and Contract Design phases, there is a high probability that information will be required that has been developed outside of the NAVSEA design tools environment. Not only may it be useful to obtain data that may have been developed by shipbuilders, created using their production oriented tools, but from a myriad of other sources as well. These data sources may include equipment suppliers, weapons system integrators, and as we migrate to an "open architecture," the pool of qualified suppliers will expand significantly. In recognition of this environment, NAVSEA and the commercial shipbuilders through the National Shipbuilding Research Program are working to identify the minimum set of information that needed to define a ship and ships systems. This Ship Common Information Model (NSRP 2008) is a multidisciplinary view of product model data and transcends life cycle phases as shown in figure 4. It is envisioned that this view will be developed in collaboration by NAVSEA 04, NAVSEA 05, the shipbuilders, and suppliers of design tools and Product Data Management tools. The owner of a specific piece of the Ship Common Information Model may have their own requirements but the content will be balanced since the stakeholders span the entire ship lifecycle.

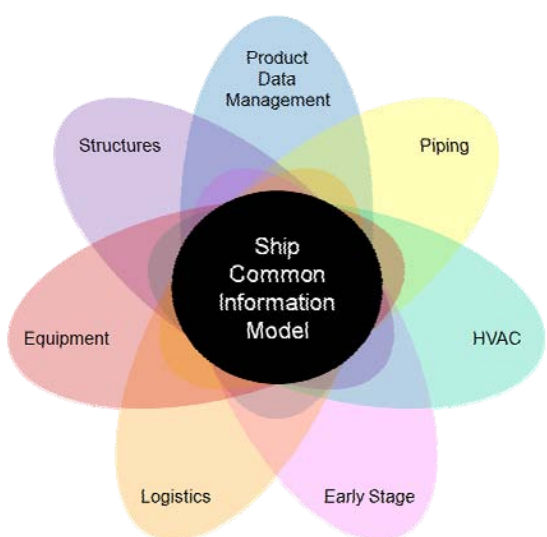

Figure 4 - Ship Common Information Model

The data obtained from the outside concentrates on the as-designed arrangement. Typically, NAVSEA would like to obtain the geometry and associated non graphical data in suitable detail and format to enable independent analysis to validate that the design meets the requirements. This means, in addition to the as-designed arrangement, NAVSEA will look to the shipbuilder to provide design data such as the (a) molded forms suitable for defining a general arrangement, (b) scantling level of detail of structure to support structural (and other types of) analysis, (c) functional distributed systems model (i.e. path, components, and connections), (e) compartmentation, including accesses, opening, and tightness, and (f) some fundamental equipment properties (i.e. weights, centers, electrical loads) . The availability of this data is a key element in enabling NAVSEA technical warrant holders and engineers to operate within the NAVSEA 05 tools environment, in accordance with VADM Sullivan's vision as stated in the 2008 memo (ref: Ser 05D/047 dtd 4 Feb 2008). It will also provide accurate data of value to the NAVSEA 04 community as they prepare to provide support for ships after they are delivered to the fleet.

DETAILED DESIGN

As a ship design progresses, the responsibility of "detailed design" is handed off to industry, and the types of models used for the design, primarily CAD and manufacturing models, are fundamentally different than the physics-based ship performance models used within the Navy. At the time the detailed design contract is awarded, the physics based analysis to ascertain whether the ship meets its requirements should be complete, and the ship design configuration should be fixed. A crucial challenge will be the ability to translate the shipyard's detailed design data back into a digital format appropriate for meshing and analyzing the performance of the designs. The lifetime of a ship class from the time the lead ship is conceived to the time the final ship is retired far exceeds the lifetime of any commercial ship design or CAD tool, and yet computer-based analysis is needed throughout the ships' life for refits, upgrades, or

damage incidents. It is crucial as well that the Navy become stewards of the digital ship design data for their assets. These are two more reasons why the Navy must continue to not only build and maintain the LEAPS system, but enforce its use.

The Navy does not do detailed design of ships, but during detailed design the Navy has a continued responsibility to be a smart customer by a continuous process of accepting data for review and performance analysis. As the design matures, NAVSEA does not need manufacturing data, but does need geometry structure, arrangements, and parts catalog data for systems and payloads. The component catalog data that is captured in LEAPS for new class specific systems will then be available for future preliminary designs, and can be easily accessed to assess commonality of future designs with those of the past.

THIS IS ONLY THE BEGINNING

This paper discussed the emerging tools, modeling, and product data integration environment being developed to support early stage naval ship design. It is true that Naval ship design was performed well before any of the advanced computational capabilities we seek today were available, but with NAVSEA at less than a quarter of the size it was in the eighties, the rising cost of ships, and the increasing complexity of technology, we cannot afford to not have the most powerful tools available. Unfortunately, this is balanced by the current budget for tool development also standing at about a quarter of what it was in the eighties (not adjusted for inflation). So the challenge grows tougher as we continue to develop tomorrow's ships with yesterday's tools.

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